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RECENT POPULATION TRENDS OF THE EASTERN BLUEBIRD

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ABSTRACT.—North American Breeding Bird Survey data for the period 1966–1987 indicate that Eastern Bluebird (*Sialia sialis*) populations declined during the 1970s, primarily in association with either severe winters or severe spring storms. In recent years, bluebird populations have increased to levels similar to those observed during the first year (1966) of the survey. Survey results suggest that climate has an important role in affecting short-term population declines in bluebirds. *Received 20 April 1989, accepted 27 Aug. 1989.*

The population status of the Eastern Bluebird (*Sialia sialis*) has been the subject of considerable public concern. Zeleny (1977) indicated that "During the past forty years, the population . . . may have plummeted by as much as 90 percent" and attributed the decline to competition with House Sparrows (*Passer domesticus*) and European Starlings (*Sturnus vulgaris*) for nest sites, to a decline in winter food supply, human-caused decreases in nest cavities, severe winter weather, and use of pesticides (Zeleny 1976, 1977). Without long-term survey data from breeding areas, it is difficult to assess the relative importance of these environmental influences on changes in bluebird populations.

Even with survey data, however, it is difficult to evaluate the effects of long-term, gradual influences (such as decreases in winter food supply, regional changes in pesticide use, or increased nest box availability) on regional bird populations, as these factors cannot be manipulated experimentally over time and space. Correlational studies must be used to associate these factors with bird population trends, and cause and effect relationships can only be implied. Studies in which environmental factors can be experimentally manipulated are necessary to document accurately the effects of these factors on bird populations (Morrison 1986).

Climatic effects on bird population sizes can be both gradual (occurring over a period of years) or severe. Effects of gradual changes in climate may be difficult to document (see above). Population changes associated with severe weather, however, can be evaluated using data from large-scale geographic surveys. Extreme weather events, such as hurricanes or cold winters, can produce measurable between-year effects on bird populations (Robbins et al. 1986). Documenting declines after periods of severe weather and subsequent population recoveries can provide insight

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into the importance of weather in influencing both the population dynamics of individual species and the structuring of communities (e.g., Wiens 1977).

Severe weather in winter and spring has been associated with declines in Eastern Bluebirds (e.g., Bent 1964). James (1962) analyzed Audubon Christmas count data and found long-term declines in wintering bluebird populations from the mid-1940s until 1961. He documented a strong correlation between cold winters and subsequent declines in Eastern Bluebird populations. However, bird distribution in winter can vary in association with climatic severity, and regional shifts in distribution can influence yearly Christmas count data. Examination of populations during the breeding season provide more accurate representations of population trends over time. Unfortunately, no breeding population survey existed in North America prior to 1966.

We now have 22 years of data from the North American Breeding Bird Survey (BBS, Robbins et al. 1986), which can be used to examine recent population changes in the Eastern Bluebirds. An earlier analysis of the BBS (Robbins et al. 1986) indicated widespread Eastern Bluebird population declines during the period 1966–1978. Extreme local (Pinkowski 1979) and regional (Pitts 1981) declines were noted in association with severe weather during the winter of 1976–1977. In this paper we document the recovery of the population during the period 1978–1987 and suggest that climatic events have been a dominant force in affecting the population trends of Eastern Bluebirds over the period 1966–1987.

METHODS

The North American Breeding Bird Survey.—The BBS is run cooperatively by the United States Fish and Wildlife Service and the Canadian Wildlife Service. Over 2000 randomly located permanent routes are monitored each year in the United States and Canada along approximately 80,000 km of secondary roads. In the eastern part of the continent, the survey was initiated in 1966; however, in the central United States and Canada most routes were begun in 1967. Each BBS route is 39.2 km (24.5 mi) long. An observer drives along the route, stops each 0.8 km (0.5 mi) and observes birds for 3 min. All birds seen or heard at a stop are recorded by species, and the number of birds of each species recorded over the 50 stops is totaled. From these route totals, we estimate population trends and annual indices of abundance. To estimate population trends, we use linear regression of year on the natural logarithm of the route counts (plus 0.5, to eliminate the possibility of a logarithm of 0). We also include observer covariables to account for differences in the ability of observers to perceive birds. Trend is defined as the slope of the year variable back-transformed (Geissler 1984) to provide an estimate of rate of change per year.

Trends for state/provinces, physiographic strata, and other regions are found by first estimating trends by physiographic strata within states. Individual route trends are weighted by average density on a route and the variance of the slope estimate to find these state/stratum estimates. These estimates are then weighted by the number of routes in the state/strata and the areas of state/strata to find regional trends. Variances of the regional trends are found by bootstrapping, a procedure involving repeated subsampling from the route trends from which regional subestimates are found (Efron 1982). Variances are then estimated from these regional subestimates, and the median of these subestimates is used as the regional trend estimate. We present trends as percent change/year. Statistical significance is assessed using z-tests (Table 1). This trend estimation procedure is similar to that discussed in Robbins et al. (1986, Appendix E), although they did not include observer covariables in their route regressions.

Estimation of annual indices of abundance.—Because the BBS is a route survey, we cannot simply average each year's counts to provide annual indices of abundance. These average counts are biased by missing route data and changes in observers (Geissler and Noon 1981). Instead, we estimate annual indices of abundance for a region by fitting a linear regression to data from each route in which the regional trend estimate has already been incorporated. The residuals from this regression represent the difference between the actual data and the predicted values given the estimated regional trend. These residuals are averaged by year over all routes in the region. They are then added to the regional predicted trend line (which is found by multiplying [to predict forward] or dividing [to predict backward] a regional mean density estimate by the regional trend estimate). Therefore, these residual indices represent the average distance from actual route data to values predicted by the regional trend estimate, adjusted for observer differences, and they provide a measure of goodness of fit of the trend line to the route data.

Eastern Bluebird population trends.—We estimated population trends for the Eastern Bluebird for three time periods: the entire BBS survey period (1966–1987), an early period (1966–1978), and a later period (1978–1987). Trends were estimated for states/provinces, physiographic strata, U.S. Fish and Wildlife Service Regions (see Table 2 for the component states), the United States, Canada, and North America (the entire survey area). Physiographic strata used in the analysis (Droege and Sauer 1989) are slightly revised versions of those presented in Robbins et al. (1986). Annual indices were estimated for states/provinces and other regions for the entire survey period of 1966–1987. We present population trend values for states/provinces, because humans tend to think in terms of political boundaries. The U.S. Fish and Wildlife Service Regions group the states into convenient north–south and east–west groups which summarize regional patterns. Strata results are presented in figures so as to clarify regional patterns in trends.

Relative density contour maps were made using program SURFER (Golden Software, Inc. 1987). Maps were made for two periods, the period of lowest relative abundance (1977–1979) and the most recent three years (1985–1987). For each period, total counts were averaged by route and mathematically interpolated using a Kriging procedure to form density contours (Ripley 1981).

RESULTS

Early years.—The map of population trends by physiographic strata illustrate that the Eastern Bluebird declined throughout most of its range during the early period (Fig. 1). Only one physiographic stratum (the Southern Piedmont region) showed significant increases, and the Prairie regions and Appalachian portions of the midwestern United States contained significant declines in Eastern Bluebird populations. This pattern is reflected in state/provincial trends, in which 18 of the 38 state/provinces showed significant declines ($P < 0.05$), and only one state (North Carolina) had an increasing population (Table 1). All FWS Regions showed signif-

TABLE 1

POPULATION TRENDS (% CHANGE/YEAR) FOR THE EASTERN BLUEBIRD BY STATE/PROVINCE FOR THREE TIME PERIODS

State	1966–87 trends			1966–78 trends			1978–87 trends		
	%	P[a]	N[b]	%	P	N	%	P	N
ALA	2.596	*	50	−4.796	*	40	8.108	**	48
ARK	−0.609		27	−2.935		26	3.667		27
CON	−7.114		15	−9.655		15	1.525		13
DEL	0.729		6	−2.072		6	23.506	**	6
FLA	−6.390	**	33	−6.958	**	31	−5.053		26
GA	2.798		58	−3.468		47	4.843	**	55
ILL	−2.073		54	−19.277	**	49	20.912	**	49
IND	−0.344		36	−16.928	**	16	11.493	**	35
IA	1.187		29	−9.490	**	25	6.870	**	25
KAN	−2.357		30	−10.253	**	30	19.943	**	26
KY	−2.936	**	44	−11.654	**	41	15.948	**	38
LA	36.897		20	0.441		17	27.503	**	14
ME	−2.817		20	−13.717		13	11.099		13
MD	3.388	*	55	−0.757		47	10.004	**	48
MAS	−3.323		13	−6.601	**	13	5.366	*	7
MIC	−6.886	**	62	−10.597	**	44	10.149		44
MIN	3.331		37	−2.485		28	16.638	**	27
MIS	3.885	*	26	1.114		22	6.475	*	23
MO	−0.487		40	−13.027	**	36	15.554	**	36
NEB	4.040		18	0.242		14	11.102		12
NH	6.780		22	2.909		21	10.692		14
NJ	0.826		13	−7.362		9	13.989		7
NY	0.155		101	−4.252	**	85	7.943	**	65
NC	7.278	**	30	5.120	**	24	7.654	*	25
ND	0.006		11	0.062		7	2.749		6
OHI	−3.867	**	43	−9.509	**	38	20.036	**	39
OKL	−1.899		32	−8.722	**	30	8.878	**	29
ONT	−2.445		42	−11.918	**	29	11.957	*	28
PA	1.809		94	0.155		75	6.546	*	64
QUE	7.773	*	11	15.668		9	11.768		7
SC	9.809	**	21	5.876		18	6.173	**	18
SD	−3.822		15	−7.709	**	10	0.193		6
TEN	−1.923	*	44	−4.027	**	42	15.277	**	42
TEX	7.313	**	64	−0.869		52	9.794	**	55
VT	−2.549	**	20	−0.184		18	−6.882		10
VA	6.131	**	46	4.667		38	11.073	**	42
WVA	−2.825		37	−10.655	**	32	5.578		30
WIS	−3.053	**	67	−6.766	**	66	19.803	**	52

[a] Statistical significance of a z-test.
[b] N indicates number of routes in the state/province.
* $P < 0.05$; ** $P < 0.01$.

TABLE 2

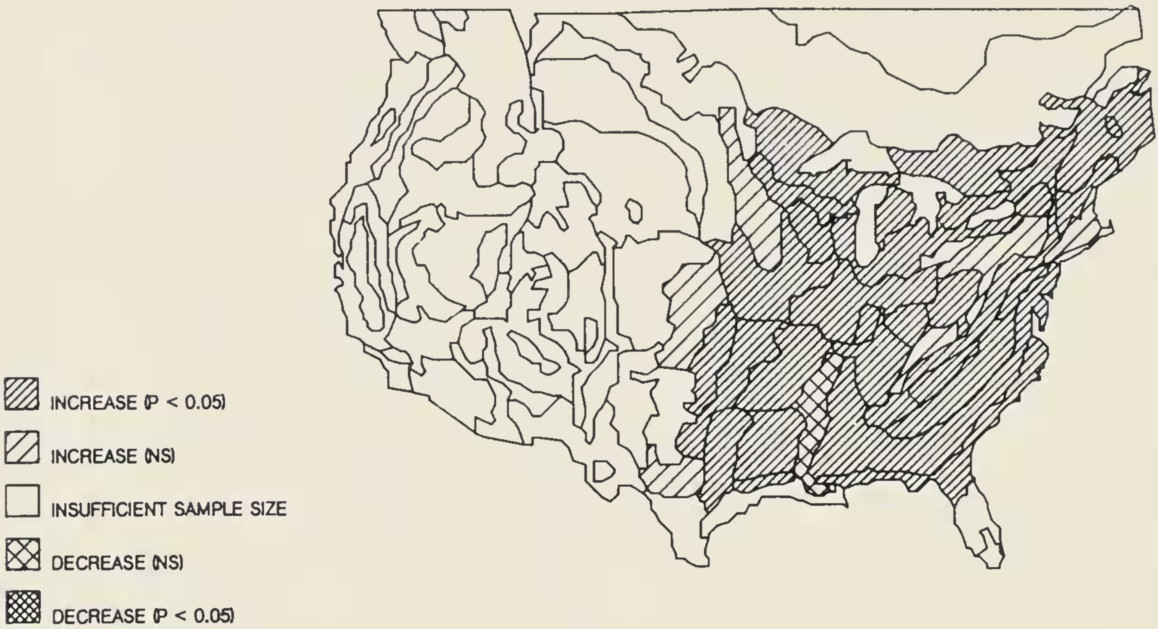
POPULATION TRENDS (% CHANGE/YEAR) FOR THE EASTERN BLUEBIRD BY REGIONS FOR THREE TIME PERIODS, WITH ASSOCIATED SAMPLE SIZES (N) AND STATISTICAL SIGNIFICANCES

Region	1966–87 trends			1966–78 trends			1978–87 trends		
	%	*P*	N	%	*P*	N	%	*P*	N
FWS Region 2 (TX, OK, MN, AZ)	1.957		99	−5.296	**	84	6.842	**	87
FWS Region 3 (MN, WI, IA, MO, IL, IN, OH)	−1.667	*	368	−11.083	**	302	15.966	**	307
FWS Region 4 (AR, LA, KY, TN, MS, AL, GA, SC, NC, FL)	0.038		353	−5.005	**	308	8.681	**	316
FWS Region 5 (ME, NH, VA, NY, MA, RI, CT, PA, DE, NJ, MD, VA, WV)	1.392		442	−4.885	*	372	8.931	**	319
FWS Region 6 (MT, ND, SD, WY, NE, KS, CO, UT)	−1.934		76	−9.128	**	61	18.108	**	50
Canada	0.524		58	−1.072		42	11.895	**	35
United States	0.119		1338	−6.549	**	1127	9.571	**	1079
North America	0.115		1396	−6.524	**	1169	9.581	**	1114

* $P < 0.05$; ** $P < 0.01$.

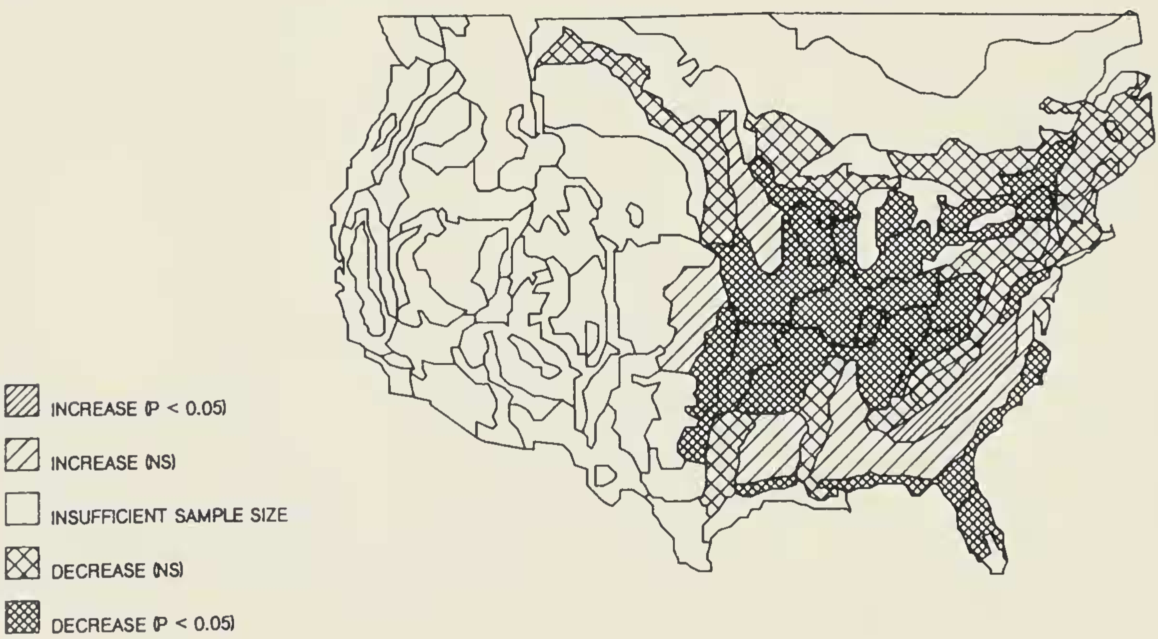
EASTERN BLUEBIRD

BBS 10 YEAR TREND 1978–87



EASTERN BLUEBIRD

BBS 13 YEAR TREND 1966–78



icant declines, as did the United States and the continent (Table 2). Canada showed a nonsignificant decline.

Late years.—Conversely, almost all physiographic strata had increasing Eastern Bluebird populations during 1978–1987 (Fig. 1). Similarly, 25 states had significantly increasing populations, and no states showed a significant decline (Table 1). All regions analyzed also had significant increases in Eastern Bluebird populations (Table 2).

Entire survey period.—Survey results reflect the patterns of the two subperiods, with the southern United States showing increasing populations of Eastern Bluebirds and more northerly strata showing generally a mosaic of nonsignificant increases and declines, except for several significantly declining populations in the Appalachian foothills (Fig. 2). State trends also reflect this variable pattern, with seven states showing significant declines and seven states showing significant increases (Table 1). Only FWS Region 3 shows a significant decline, and all other large regions showed nonsignificant declines or increases (Table 2). The United States, Canadian, and the North American trends were slightly positive.

Annual indices of abundance.—We present annual indices of abundance for selected states (Fig. 3) and regions (Fig. 4). Annual indices show several patterns of population change among states. Some states are generally increasing (e.g., Georgia and Virginia), while other states are consistently decreasing (e.g., Florida and Vermont). Many states, however, show a quite variable pattern of decline then increase, with the minimum year of either 1978 or an adjacent year (e.g., Alabama, Iowa, Kentucky). FWS Regions 3, 4, and 5 all show generally similar patterns of year-to-year change, with a population minimum in 1978 and high years in 1972 and 1983. United States indices show similar highs and lows and are virtually identical to the North American indices (not shown).

Relative density maps.—The density changes associated with the 1978 population low are strikingly illustrated by the relative density maps (Fig. 5). Density contours shift dramatically between the two maps. Many routes in the central part of the Eastern Bluebird range did not record bluebirds during the population low.

DISCUSSION

Effects of weather.—We have documented a short-term "crash" in Eastern Bluebirds and their subsequent range-wide recovery using BBS data.

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FIG. 1. Maps of the geographic distribution of increasing and decreasing populations of Eastern Bluebirds for early (1966–78) and late (1978–1987) survey periods from analysis of population trends by physiographic strata.

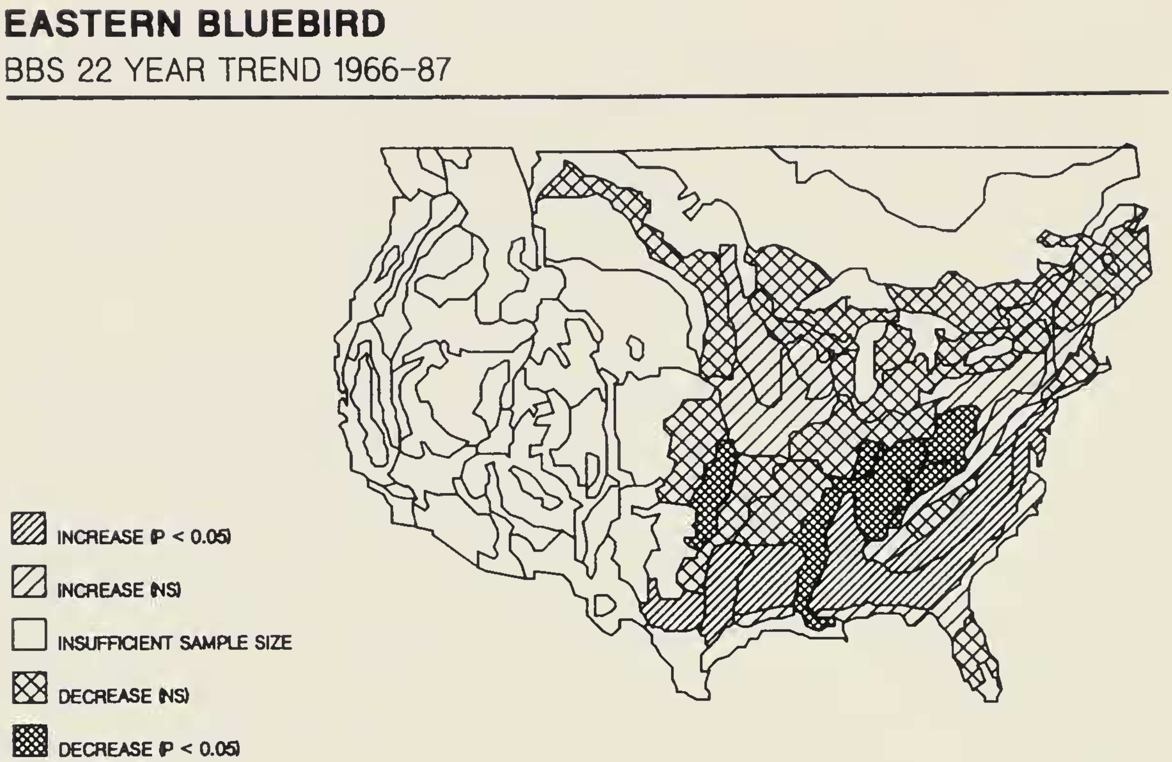

FIG. 2. Map of the geographic distribution of increasing and decreasing populations of Eastern Bluebirds for the 1966–1987 survey period, from analysis of population trends by physiographic strata.

Annual indices of abundance (Figs. 3, 4) provide evidence that extreme declines occurred in many bluebird populations in 1977 and 1978. These large population declines occurred after the 1976–1977 and 1977–1978 winters which were unusually severe (Kerr 1984, Robbins et al. 1986). Rapid declines in Eastern Bluebird populations have been documented for local and regional bluebird populations in the past (e.g., Musselman 1941, Graber and Graber 1979), and these declines are usually associated with severe weather. Robbins et al. (1986) documented an extreme decline in wren populations (especially Carolina Wrens [*Thryothorus ludovicianus*] and Winter Wrens [*Troglodytes troglodytes*]) in the eastern United States in association with severe winters in 1976–77 and 1977–78. These declines were most apparent in the northern portion of the eastern Piedmont, where Eastern Bluebirds also experienced their strongest declines (Fig. 1).

Weather in spring can also influence population changes, as Hurricanes Abbey (in 1968) and Agnes (in 1972) correspond to drops in annual indices of abundance (Figs. 3, 4). These population declines may be due to mortality associated with cold weather during the peak (for Abby) or late (for Agnes) breeding season in spring. Purple Martin (*Progne subis*) populations also experienced population declines in association with these storms (Sauer et al. 1987).

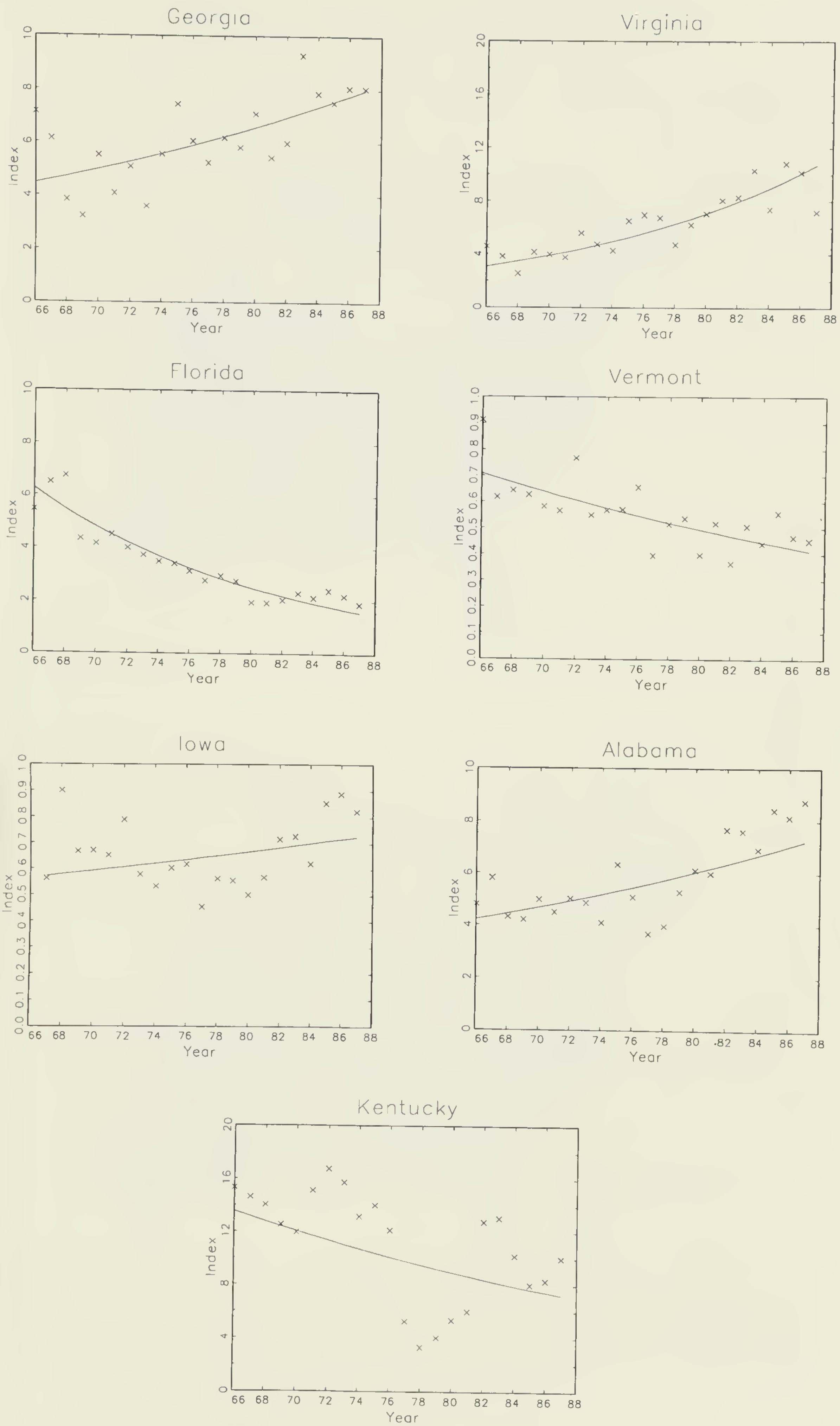

FIG. 3.—Annual indices of abundance for selected states from BBS d

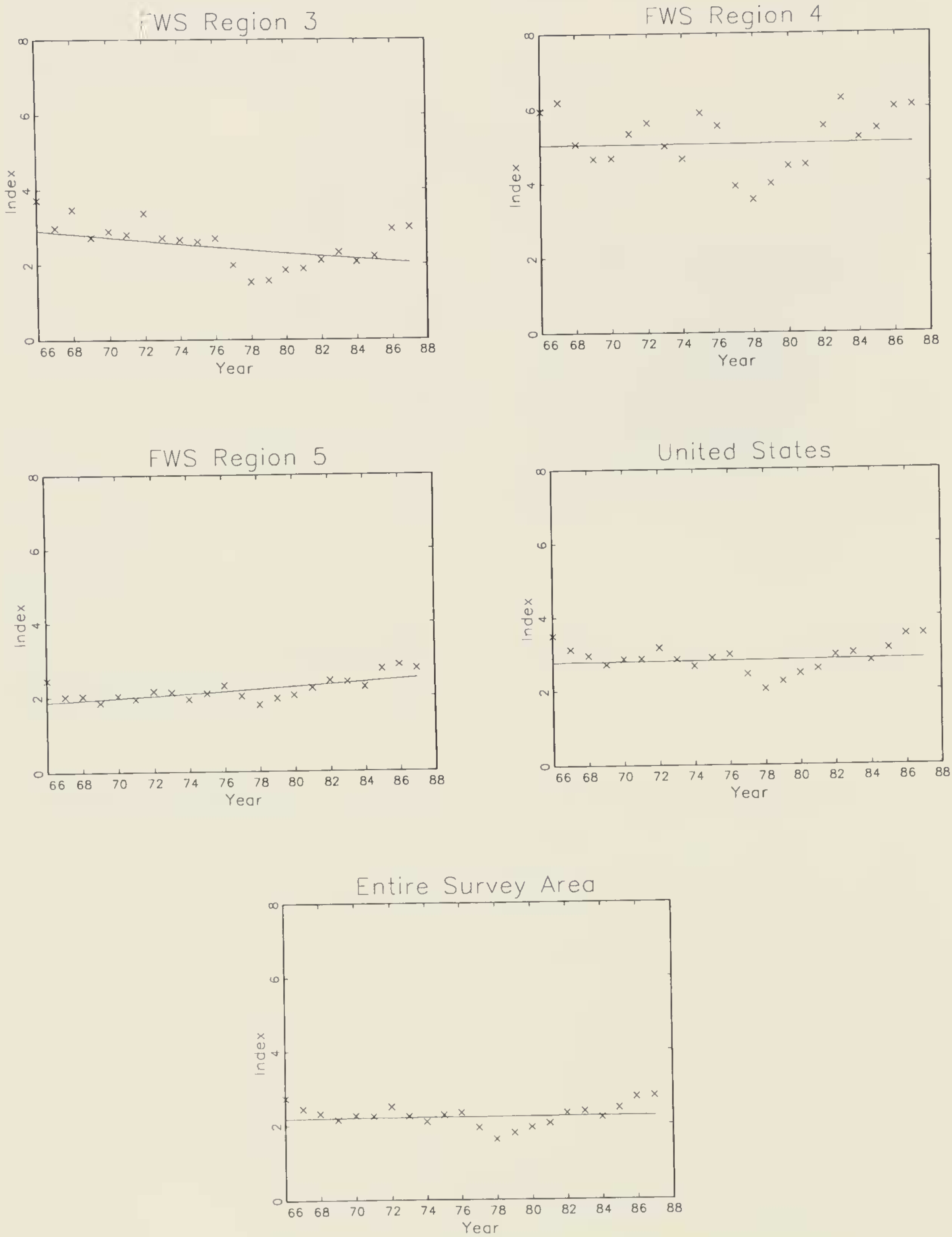

FIG. 4. Annual indices of abundance for selected regions from BBS data.

Population regulation in bluebirds.—Wiens (1977) suggested that bird community structure and species population dynamics are affected by periods of severe climate which keep populations below levels at which competition between species could play a major role in structuring com-

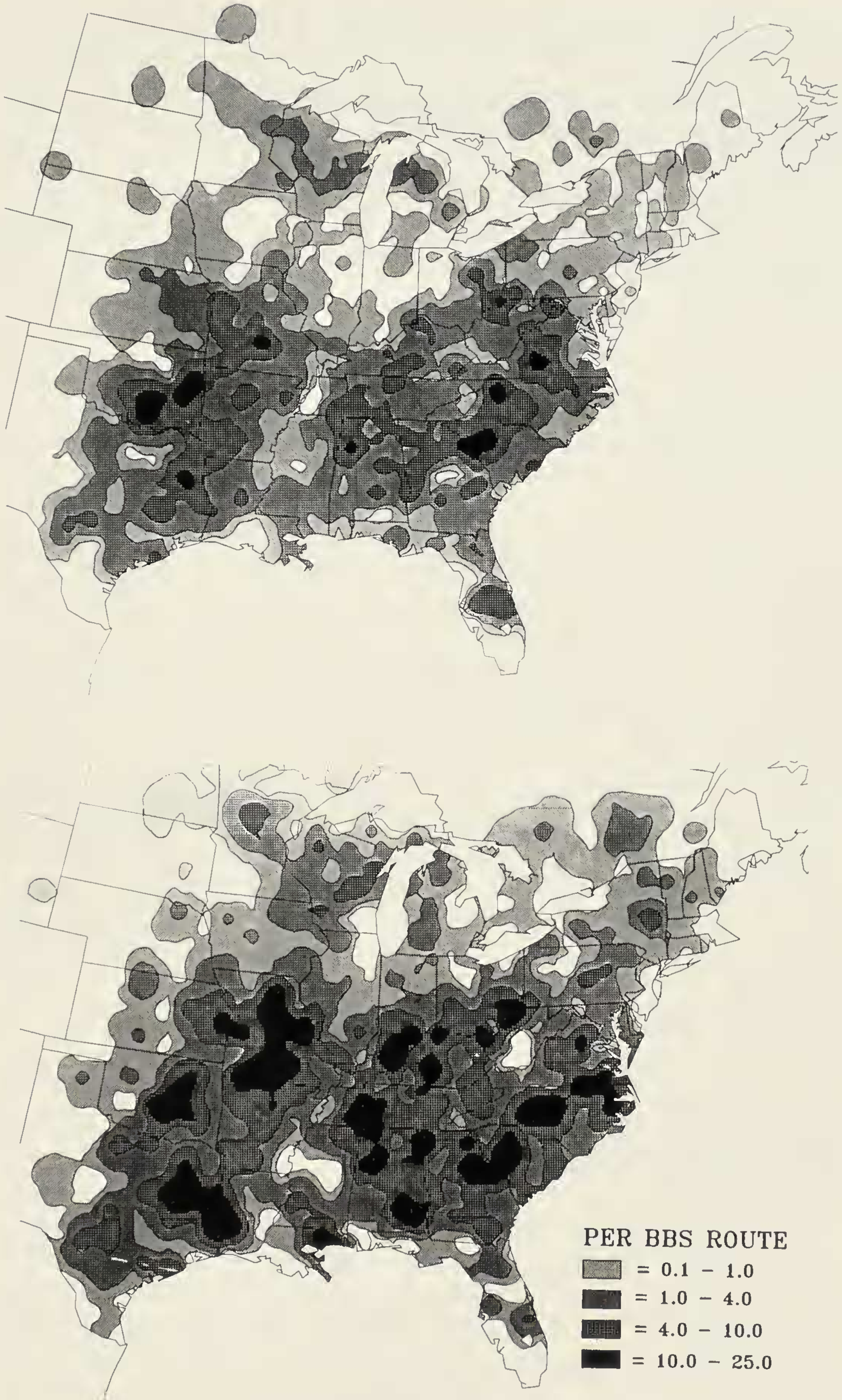

FIG. 5. Relative density contour maps for two time periods: a population low (1977–1979) and a higher density period (1985–1987).

munities. Information from the BBS indicates a short-term decline in the Eastern Bluebird in the 1970s, but a population recovery through the 1980s. These results indicate that Eastern Bluebirds experience "ecological crunches" that, at least in the time period we examined, can dominate bluebird population trends.

Statistical methods exist for the analysis of density-dependency from series of annual censuses (Pollard et al. 1987). It is unclear whether these methods are appropriate for analysis of BBS data because annual indices of abundance may contain both autocorrelation and measurement error which could invalidate the results of the methods (Pollard et al. 1987). However, we note that when this method is applied to annual indices from 35 states and provinces (eliminating states/provinces with extremely low densities) the null hypothesis of complete density independence was rejected in 10 states/provinces. These results suggest that some evidence of density-dependent population regulation exists in bluebirds. However, we feel that analysis of survey data can provide at best limited information regarding the extent and causes of density dependence and that population regulation should be examined through studies of local breeding populations.

Densities of cavity-nesting birds can be limited by the availability of nest sites. Bellrose (1976) determined that Wood Ducks (*Aix sponsa*) were limited by the availability of nesting sites at a study site in Illinois and documented an increase in population size when nesting boxes were placed on the study site. Bluebird populations may have been particularly affected by competition for nest sites (Zeleny 1976), hence the addition of nest boxes throughout the breeding range of the Eastern Bluebird during the 1970s could have influenced bluebird populations. Unfortunately, we do not have information on regional changes in nest-box availability and cannot determine if a correlation exists between changes in nest-box abundance and bluebird population changes.

Short-term versus long-term trends in bluebird populations.—In any fluctuating population, relatively short-term changes tend to mask long-term population trends. For bluebirds, selection of the interval from which trends are estimated can greatly affect the perception of population trend. Earlier analyses of bluebird trends (e.g., Pitts 1981, Robbins et al. 1986) examined an interval corresponding to our early period, when bluebird populations were decreasing. Our analysis of the period 1966–1987 documented no trend, as the population has increased to levels similar to those noted in 1966, when the BBS was initiated. These results emphasize that survey data can be greatly influenced by short-term effects, and population trends estimated from variable populations contain an environmentally induced "noise" component that can sometimes be more evident than a longer-term trend.

Local environmental conditions can cause Eastern Bluebirds to disappear from portions of their range in a relatively short time (Pinkowski 1979, Pitts 1981). However, locally derived data may not reflect regional population changes, and winter severity often varies regionally. Actual regional population changes can be evaluated accurately only by using an extensive survey such as the BBS, which minimizes the bias associated with examination of limited geographic regions.

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